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Mariner Mars 1971 Science Operational Support Equipment Final Report

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
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PREFACE

The work described in this report was performed by the technical divisions of the Jet Propulsion Laboratory, under the cognizance of the Mariner Mars 1971 Project.

ACKNOWLEDGMENT

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CONTENTS

ABSTRACT

The Mariner Mars 1971 science operational support equipment (SOSE) was developed to support the checkout of the proof test model and flight spacecraft. This report discusses the test objectives of the SOSE and how these objectives were implemented. Attention is focused on the computer portion of the SOSE, since incorporation of a computer in ground checkout equipment represents a major departure from the support equipment concepts previously used at JPL. Also included is a functional description of the major hardware elements contained in the SOSE, along with the operational performance of the SOSE during spacecraft testing.

I. INTRODUCTION

The Mariner Mars 1971 (MM '71) SOSE was developed to provide test support of the science subsystems on the MM '71 spacecraft.

RCA designed, fabricated, and checked out two SOSE systems. The SOSE Group at JPL provided functional and design requirements and technical support, and conducted the SOSE acceptance test using a payload simulator designed and fabricated by the SOSE Group. Both the SOSE and the payload simulator incorporated a mini-computer as the primary testing device. This approach provided an extremely flexible set of support equipment and was a major departure from the all-hardware operational support equipment (OSE) used on previous programs.

The two SOSE's were shipped from RCA to JPL on 4/8/70 and 5/14/70. After completion of the integration checkout, the SOSE's were used continuously in support of the tests conducted on the proof test model (PTM) and flight spacecraft through the first trajectory-correction maneuver of Mariner 9. During this period, modifications (primarily to the computer software) were incorporated in response to requests by test personnel and changes in spacecraft requirements which significantly increased the testing capability of the SOSE.

II. SOSE FUNCTIONAL DESCRIPTION

A. Test Requirements

The following requirements were established for the SOSE:

1. Provide continuous evaluation of the science payload consisting of the data acquisition system (DAS), TV, infrared interferometer spectrometer (IRIS), ultraviolet spectrometer (UVS), and infrared radiometer (IRR).

2. Provide the capability for problem isolation to the subsystem level without removal of subsystems or alteration of the test configuration.

3. Support the ability of other support equipment to perform its functions by supplying processed or unprocessed data as necessary.

4. Provide control and power for stimuli which exercise the science instruments through specific modes of operations.

5. Provide external power and signals required for operation of the science payload independent of the spacecraft.

6. Simulate science payload functions (including DAS formated data streams) as an aid to troubleshooting and program development for both the SOSE and the mission test computer (MTC).

B. Test Configurations

The SOSE was designed to operate in three testing configurations. The subsystem configuration was used to integrate the science payload for the first time on PTM spacecraft. This configuration uses all of the direct access cables as in the system test configuration; in addition, the SOSE provides the science payload with 2.4 kHz power, which is switched on in the identical manner as on the spacecraft. The SOSE also provides central computer and sequencer (CC&S) and flight command system (FCS) commands which control the science payload operating modes.

The major portion of spacecraft testing was accomplished in the system configuration. All direct access cables between the SOSE and the

science instruments and DAS are used for analog and digital data acquisition and stimulus control.

In the launch pad configuration, the SOSE provides power and control for the TV, IRR, UVS, and IRIS on-pad stimuli. The SOSE also processes recorded science format (132.3 kbps), which is received over a 12-km cable link, and the orbital science format (RTS1) or spectral science/selected video format (RTS2) received from the flight telemetry system (FTS) support equipment.

C. Physical Description

One set of SOSE consists of seven standard 1.8-m equipment consoles, a teletype character printer, a data products line printer, and a pair of remote display consoles. These sets of equipment are shown in Figs. 1 and 2.

The payload simulator, which was used to support both SOSE's along with MTC and spacecraft checkout, consists of three standard 1.8-m equipment consoles and a teletype character printer. The payload simulator is shown in Fig. 3.

III. HARDWARE/SOFTWARE

A. SOSE Block Diagram

Figure 4 shows the SOSE block diagram. Interfaces with the spacecraft are presented at the left side of the diagram. "Umbilical lines" are the 132.3 data and sync connection to the DAS, which is used during all modes of SOSE operation. "DAS and inst. direct access" is the science payload interface used during payload integration and system test configurations of SOSE operation.

The spacecraft simulator is used only during payload integration. The CC&S/FCS Sim block provides commands to the science payload during payload integration. This panel can be used to generate any of six CC&S commands and any of three FCS discreet commands, as well as any FCS 18-bit coded command to the DAS.

The signal generator, umbilical/spacecraft switch, and launch complex remote equipment are located in the launch complex equipment (LCE) chassis. LCE remote provides the circuitry necessary to interface with the DAS and drive the 12-km cable linking the pad area to the SOSE. The signal generator may be used to verify the 12-km link. The self-test signals entering this box can be used only when the LCE remote chassis is local.

The LCE local chassis contains receiving circuitry for the 12-km link and controls for selecting the MTC and SOSE data source. An operator control permits selection of a self-test signal or the normal spacecraft signals for routing to the MTC. When self-test is selected, all the formated data streams supplied to the MTC will contain the same information at the same frequency determined by the SOSE computer. The actual switch contacts for this selection are located in the LCE local chassis and the signal monitor.

As an operator function independent of the MTC self-test selection, FTS OSE or normal payload signals can be selected as the data source for SOSE. Other controls on LCE local enable the operator to define the format and frequency that FTS OSE is delivering to SOSE. A self-test switch control on the LCE local enables the operator to select either normal or self-test signals as the SOSE input.

The system test simulation power control and LCE stimulus power control contain manual on/off controls for the instrument stimuli. The positions of the on/off control switches are made available to both MTC and the SOSE computer.

The signal isolation and conditioning circuits provide isolation and buffering of most payload signals. (As indicated above, some of the signal source selection is also performed by this circuitry.) In general, both the isolated and unisolated versions of each signal are made available at the patch panel manual signal selection. This capability is used to select any desired signals as inputs to the standard test equipment. The visicorder has 12 channels, eight of which are permanently assigned to specific parameters. Four channels are available for assignment via the patch panel. Each visicorder channel has a manual on/off control as well as manual calibration capability. One channel is permanently assigned to the recording of time. This channel is driven by a time formater, which provides NASA time to the visicorder.

TV framing and comparison achieves pseudo-noise (PN) lock on the 132.3 and 16.2/8.1 data, and converts these data to the form and timing required by the various computer interface circuits and the signal processing logic. TV framing and comparison performs a similar function on some of the direct access control signals from the payload and also compares the 176.4 TV direct access data to TV data contained in the 132.3 data.

The signal processing and TV bench checkout equipment (BCE) interface equipment includes digital-to-analog (D/A) conversions for digital picture information, the control panel for the local TV monitors, and the interface for the TV BCE. A pattern generator for testing is included in this equipment. Major functions of the control panel include selection of the pattern generator or any of several analog and digital forms of picture information for display on the local monitors.

The 50-bps interface logic achieves PN lock on the 50-bps data, converts from serial to parallel, and makes the data available to the computer. The 8.1/16.2 interface and the 132.3 interface provide the functions of buffering and control of the data flow to the computer.

The IRIS science logic converts serial science data into 12-bit parallel words for input to the computer and to the IRIS science D/A. Buffering is provided for both. Direct access control lines are used to frame the 12-bit words from the serial stream. The IRIS status logic handles the 7 bits of status information in a similar fashion.

The IRR analog-to-pulse width (A/PW) converter and UVS A/PW converter blocks duplicate the analog-to-digital (A/D) conversions performed in the payload, buffer the digital data, and make them available to the computer. In order to do this, some of the direct access signals are processed in these blocks.

The status interface logic buffers and makes available to the computer miscellaneous status information, such as NASA time, position of the spacecraft/FTS selection switches, mode and status lines from the payload direct access interface, manual requests from the remote display, etc.

The IRIS and UVS output D/A logic provides control and buffering between the computer and three of the permanently assigned visicorder channels. This logic also provides rate adjustment to compensate for the variation in input rates during some operations with FTS OSE.

The self-test interface provides a built-in programable test capability. The computer program will specify any one of four data rates to this logic. The logic will then monitor a continuous flow of data at the specified rate of all of the self-test points indicated in the block diagram. This is accomplished by requesting data from the computer as required to sustain the rate.

B. SOSE Computer and Processing

The Varian computer main frame, its options, and the rack-mounted peripheral equipment are mounted in two standard 1.8-m racks. The teletype, line printer, and card reader are free-standing devices.

The Varian 622/i is a small (26.8-cm rack space) general-purpose digital computer which uses ferrite magnetic core memories along with diode/transistor logic (DTL) and transistor/transistor logic (TTL) integrated circuits. The Varian has a word length of 18 bits with a memory

cycle time of 1.8 μs. The Varian main frame options used in the SOSE system are:

1. 12,288 words of core for a total of 16,384 words for one SOSE system
2. Extended addressing
3. Direct memory access and interrupt logic
4. Power fail detect/restart
5. Priority interrupt (16 channels)
6. Three buffer interface controllers

The following peripheral equipment is also used with the SOSE computer system:

1. Vermont drum (110,000 words)
2. Teletype ASR 35 typewriter
3. Data products line printer
4. Tally paper tape punch (150 characters/s)
5. Uptime card reader (200 cards/min)
6. Remex paper tape reader (300 characters/s)
7. Remex paper tape spooler

The drum is used for storage of the SOSE operating program, self-test programs, and computer diagnostics. The program portion of the drum is always write protected during operations to ensure that the operating program cannot inadvertently destroy any of the stored programs. The remainder of the drum is used for bulk storage of data, which is transferred to the line printer.

Not only does the drum provide the necessary storage for the line printer but, because of its fast sector access and transfer rates (16 ms and 100,000 words/s, respectively), it minimizes the amount of time required to change SOSE operating modes. The only resident programs in core are the loader bootstrap and a drum routine which allows the operator to select the programs transferred from the drum with the TTY.

The TTY and status panel switches are used during operations for the selection of data streams and the processing which will be done on individual data. The TTY is used to select for processing any or all of the three formats from the DAS, the source of the RTS1 data, and the source of the UVS and IRIS data. This feature was incorporated to allow the operator to have the maximum amount of flexibility in choosing the configuration best suited to a given situation. For example, the RTS1 data may be extracted from the 132.3-kbps format if the direct access RTS1 is not available, as during on-pad testing and tape recorder playback. Processing of the UVS and IRIS data may be selected from either the 132.3-kbps, RTS2 formats or direct access, again depending on the testing requirements.

Controls at the status panel allow the operator to choose the processing which will be done on each instrument's data. This selection includes comparison of decommutated data to the data received directly from an instrument, response of instruments to specific commands, and evaluation (format verification, tolerance testing, etc.) of instrument data. The status panel indicates what processing has been requested and also whether the computer is actually responding to the requests. This provides the operator with immediate knowledge of the processing status.

The DAS high-rate data stream (132.3 kbps format), data to and from the drum, and self-test data to the SOSE are all transferred to and from the computer with the buffer interlace controller and direct memory, with a minimum amount of software intervention. The remaining formatted data streams, data to the visicorder D/A's, and the high-rate events are transferred on response to a priority interrupt system on the bidirectional computer bus. Status and low-rate data are transferred and processed at a 60-ms interval.

Data received from DAS are decommutated and tested for proper formating, which includes PN, line count, pic count, DAS time, and frame count verification. Discrepancies are displayed as an error on the status panel and printed on the line printer with an appropriate message and the received/expected data. Data which are identical in these three formats are compared with each other, and errors are displayed on both the status panel and line printer. Tests are also made on all of the decommutated

instrument data. These tests include a tolerance test of the UVS data and tolerance, alarm limit, and sequence tests of the IRR and TV data. IRIS data are tolerance-tested in the interferogram and zero path difference portions of the data. Sequencing and temperature alarm limit testing is also performed on the IRIS data. Detected errors are both displayed on the status panel and printed.

UVS and IRIS data selected from either the 132.3-kbps or RTS2 8.1-kbps are decommutated by the computer and clocked to D/A converters in the input/output (I/O) logic. The resulting rate-smoothed analog data are displayed on a visicorder to aid in performance analysis. TV picture data displayed on the SOSE TV cathode-ray tube (CRT) monitors are annotated with DAS time decommutated from the 132.3-kbps format by the computer.

A total of eight printer formats have been developed for real-time and off-line science subsystem analysis. One format exists for an IRR scan, UVS spectrogram, RTS1 full frame, RTS1 status, and IRIS housekeeping and engineering data from all instruments. IRIS science data may be printed in either a linearized decimal or an octal format. Only one format may be selected at a time because of the limitations imposed by the high data rates, core size, and one printer display system.

Data received directly from the IRR and UVS are converted to a digital form using A/PW converters with the same characteristics as those used on the spacecraft. The computer stores the converted data and compares them with those data samples derived from the DAS formats. Out-of-tolerance discrepancies are displayed on the line printer.

Commands and events received by the computer are recorded on the line printer with appropriate 60-ms time tag information. Also recorded are any changes in stimuli, SOSE operating modes, and processing requests. Control signals from the DAS which have known timing relationships to the DAS formats are accumulated for a specific period of time and tested for the correct number of occurrences; all discrepancies are displayed on the status panel and printed.

C. Payload Simulator Block Diagram

Figure 5 shows the payload simulator block diagram. The computer and hardware logic operate together to generate DAS formats and commands as well as TV, UVS, IRR, and IRIS direct access data. The clock and counter logic provides the basic timing for the entire system. This logic generates

1. All DAS commands received by the SOSE via the direct access. Predictable errors controlled by the operator can also be induced into these command lines.
2. Data input and output requests to the computer.
3. Shift, control, and strobe signals to the other logic elements.
4. Mode changes based on operator and computer controls.

Data buffer logic receives formated data as 18-bit words from the computer, provides temporary data storage, and shifts the three formated data streams at 50 bps, 132.3 kbps, and 8.1/16.2 kbps to the interface circuits for transmission to the SOSE (the 132.3-kbps formated data are also sent to the flight data storage subsystem (DSS) for test purposes). Included in this logic are phasing buffers for duplication of the formats as received by the SOSE from the FTS support equipment.

The TV data processor generates a 176-kbps TV data stream from the 132.3-kbps data. TV data precede the 132.3-kbps data by 10 bits to simulate buffering by the DAS. This logic converts the 176-kbps binary data to baseband video with a D/A converter and also converts the baseband video to a modulated carrier video.

Digital-to-analog converter logic receives UVS and IRR binary data from the computer and converts these to analog waveforms for transmission to the SOSE. The binary data are converted to analog at a time preceding the A/PW conversion signal to ensure that the amplitude will be at the correct level for conversion and comparison by the SOSE.

Commands (CC&S and FCS DC and CC) received from the SOSE spacecraft simulator are stored in the command decode logic. The computer translates these commands into the appropriate responses to simulate the DAS, i.e., change the RTS2 data rate, stow IRIS, etc.

D. Payload Simulator Computer and Processing

The Varian computer main frame, its options, and the rack-mounted peripheral equipment are mounted in two standard 1.8-m racks. The free-standing teletype is an additional option. The Varian computer main frame options used in the payload simulator are:

1. 8,192 words of core for a total of 12,288 words
2. Extended addressing
3. Direct memory access and interrupt
4. Priority interrupt (16 channels)
5. Two buffer interlace controllers
6. Two digital I/O controllers
7. One buffered I/O controller

The following peripheral equipment is also used with the payload simulator computer:

1. Teletype ASR 35 typewriter
2. Remex paper tape reader (300 characters/s)
3. Remex paper tape spooler

Both the SOSE and the simulator use source punched cards and object paper tapes for assembly and initial loading of the operating programs. The payload simulator operating program resides in the computer memory since the simulator does not contain a virtual memory as does the SOSE system. A Varian utility program (AID) also resides in core and is active as a simulator background program. AID provides the operator with the capability to modify some of the data patterns and is communicated with via the TTY.

After initialization, the simulator program waits until a specific interrupt (A- or B-frame start) is received from the logic to synchronize all software buffers. After this occurs, the program responds to input and output requests by generating the data listed below. These data streams are generated simultaneously, and all are time- and bit-synchronized as they would occur from the spacecraft. Note that all data which should be identical in different data streams are identical in the simulated data streams. For

example, UVS and IRIS data contained in line n of the 8.1-kbit format are duplicated in the flyback of line n + 1 of the 132.3-kbit format.

1. 132.3 kbit — Contains all DAS-related ID data (PN, TV line count, TV frame count, DAS time, etc.); also, UVS, IRIS, TV, and RTSl data are inserted into their proper locations.

2. RTS2 (16.2 or 8.1 kbit — Contains all DAS-related ID data, along with UVS and IRIS data in the 8.1-kbit format and TV data in the 16.2-kbit format. RTSl data are inserted in both formats.

3. RTSl — Contains all status bits, ID (frame count, picture count, DAS time, etc.) IRIS subcomm, IRIS and TV engineering, and IRR data.

4. IRIS 2.7 kbit — Contains housekeeping and science data, broken up and inserted into the 132.3- and 8.1-kbit data streams in the same manner as is done by the DAS.

5. FTS data — The 16.2- or 8.1-kbit data listed above are converted to bursts to simulate the block-decoded FTS stream. RTSl data are also generated in the FTS configuration. Playback data may also be selected where the 132.2-kbit data are slowed down to one of the selected playback rates and converted to bursts to simulate the FTS block-decoded stream.

When commands are received from the spacecraft simulator, the appropriate status bits are changed in the DAS formats. These input commands will also result in the appropriate output commands (correctly synchronized); for example, receipt of a 20D will generate a tape start command at TV A-frame line 684 and a tape stop at TV B line 1. The two types of commands (cyclic ones and those generated as a result of other commands) are generated correctly synchronized to the data streams. Errors can be created for each command separately or for any number of commands simultaneously.

TV, IRIS, UVS, and IRR data are dynamically changed in the direct access and formated data streams in the following manner:

1. TV — One of six patterns may be selected; these patterns range from a shade of grey to a mixture of shades of grey and alternate black and white pixels.

2. IRIS — Duplicates the format of IRIS data with eight groups of housekeeping (bracketed by PN's); each HK value is changeable, and a binary word contains scan position, in/out of lock, etc., information. Interferogram data are simulated by ramps which cover the complete range of the IRIS.

3. UVS — Data for each channel are simulated with opposing ramps of data which cover the UVS data range.

4. IRR — Each scan position of each channel is a different static value which can be changed. A stow command makes all scan values equal the reference value; temperature and voltage values remain the same.

IV. TEST AND OPERATIONS

The first SOSE was delivered to JPL with some known deficiencies (primarily in the software area); however, it was capable of adequately supporting the initial integration phase of the PTM DAS and science instruments. Activities were split into two shifts. The first shift was used for integrating the spacecraft subsystems with each other and with the SOSE. The second shift was devoted to debugging the computer programs and correcting the remaining hardware problems. The payload simulator was used exclusively to support the second shift and proved to be a very valuable test device. In fact, even after the SOSE was completely operational, the payload simulator was in heavy demand by the MTC area to support their system program development.

System test activities started on the PTM spacecraft approximately three weeks after the first SOSE was delivered to JPL. After one year of operations, during which time the two SOSE's were used to support three spacecraft, a total of 33 problem failure reports (PFR) were written against the SOSE's. The PFR's can be grouped into the following categories: 13 hardware (logic and cables), 10 commercial equipment (power supplies, oscilloscopes, etc.), 6 equipment adjustments, and 4 on software problems. These problems were either corrected immediately by spare substitution or after the conclusion of a test using the payload simulator; however, no test was cancelled or excessively delayed as a result of a SOSE problem.

The SOSE was designed primarily as a testing device, and therefore was able to produce only a limited amount of raw data for off-line analysis. Utilization of and requests for data provided by the SOSE increased as it became apparent that the processing expected by other support equipment would not materialize as expected. These requests resulted in many modifications to the SOSE but fortunately very few required changes to the hardware, which typically are more difficult to implement than software changes. The majority of the changes were to the computer software; this allowed the modifications to be coded in parallel with test operations and checked out off-line using the payload simulator as a data source. Following is a summary of the major modifications incorporated in the SOSE:

1. Three discreet TV lines of each TV frame were provided as synchronization points for A traces.

2. SAF and pad stimulus controllers were modified to provide a wider control range.

3. Peak values of each IRIS interferogram were located and displayed.

4. A parity test of each IRIS interferogram was performed and compared to IRIS-generated parity data.

5. An audio-visual alarm, triggered by an out-of-tolerance condition, was added for the IRIS IR detector temperature.

6. IRR scan positions were identified, and reference data tolerance was tested.

7. IRR science data were converted to engineering units and displayed during environmental chamber operations.

8. A tolerance table and spacecraft status displays were added to printer formats.

9. An FTS-SE block decoder test program was added.

10. Spacecraft engineering data were received, decommutated, and displayed on a line printer.

During the operations period, the SOSE was used numerous times to isolate and aid in the diagnosis of problems within the science payload. These problems are too numerous to mention here, and they are already well described in the PFR's. Some of the problems are discussed below to give an example of how the SOSE was used for problem recognition and isolation.

1. The IRR DC-48 spacecraft interface circuit was marginal — the printout from the SOSE indicated that the IRR become stowed without the issuance of a DC-48.

2. The IRR data from one channel were zero when in the stowed position — an out-of-tolerance condition was printed at the SOSE; printouts cf data from both channels verified the problem. Direct access analog data from the IRR indicated that the problem was in the IRR.

3. The CC&S issued short commands to which DAS did not respond — the SOSE verified a truncated CC&S command pulse by not receiving an event printout and monitoring waveform characteristics of the direct access signal.

4. There was a UVS Channel F anomaly — the digitally converted UVS direct access analog was matched up to the UVS data in the DAS format by the SOSE, indicating that a problem existed with the UVS.

5. An IRIS failure occurred a short time after turn-on — the data printout at the SOSE went to all zeros, direct access data was identical, format and out-of-tolerance errors were also printed.

The SOSE did have some problems while in support of spacecraft testing; however, these problems were relatively minor in comparison to the level of support provided. Some of the difficulties were certainly due to the fact that the SOSE used a completely new (at JPL) approach to support equipment by replacing the all-hardware system employed on previous programs with a hardware/software system which incorporates a mini-computer. The computer-based support equipment was developed to support a complex spacecraft system in the most efficient and effective manner possible. That this was accomplished is attested by the results.

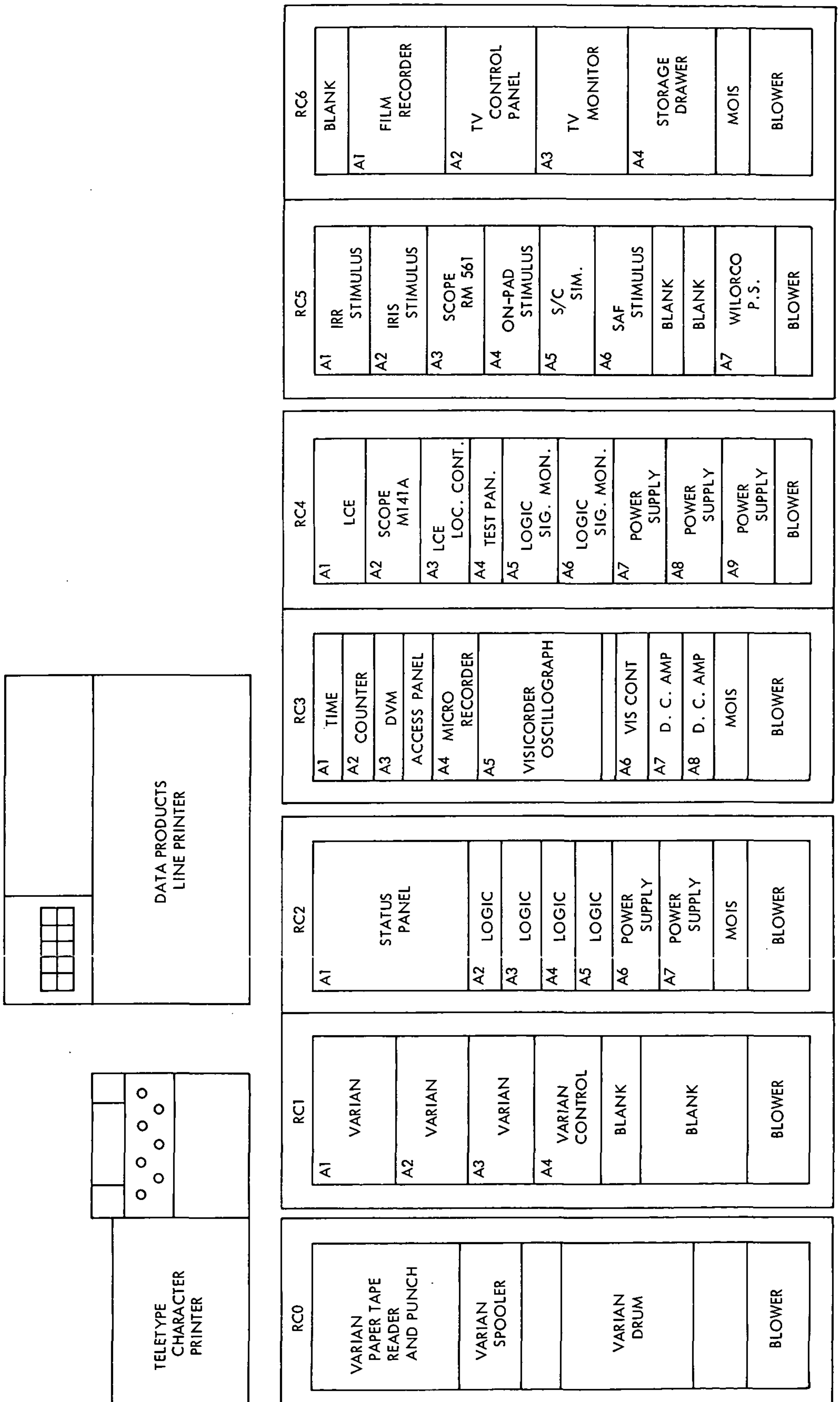

Fig. 1. SOSE consoles

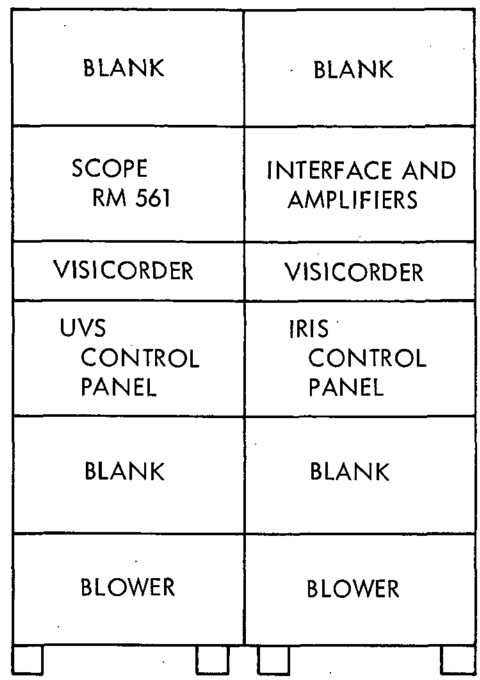

Fig. 2. Remote display consoles

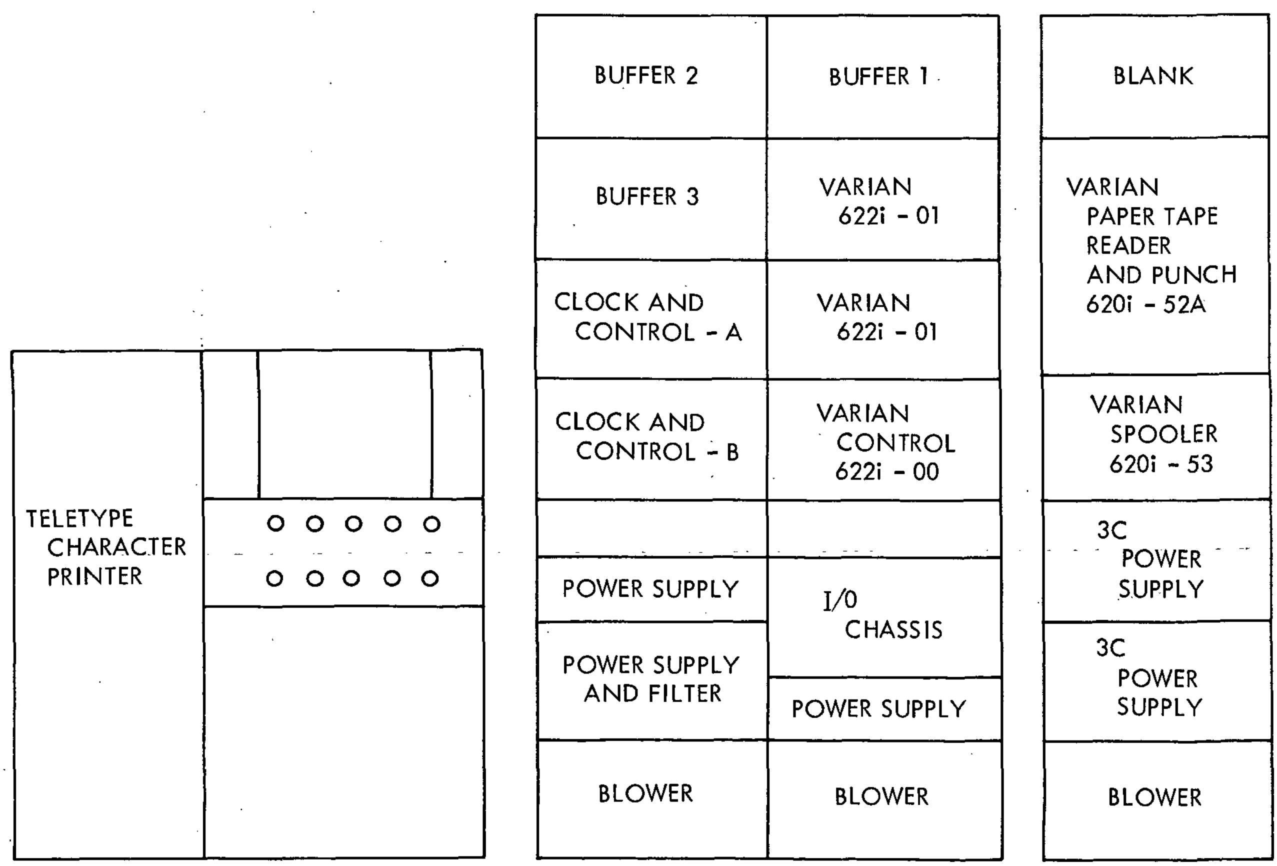

Fig. 3. Payload simulator consoles

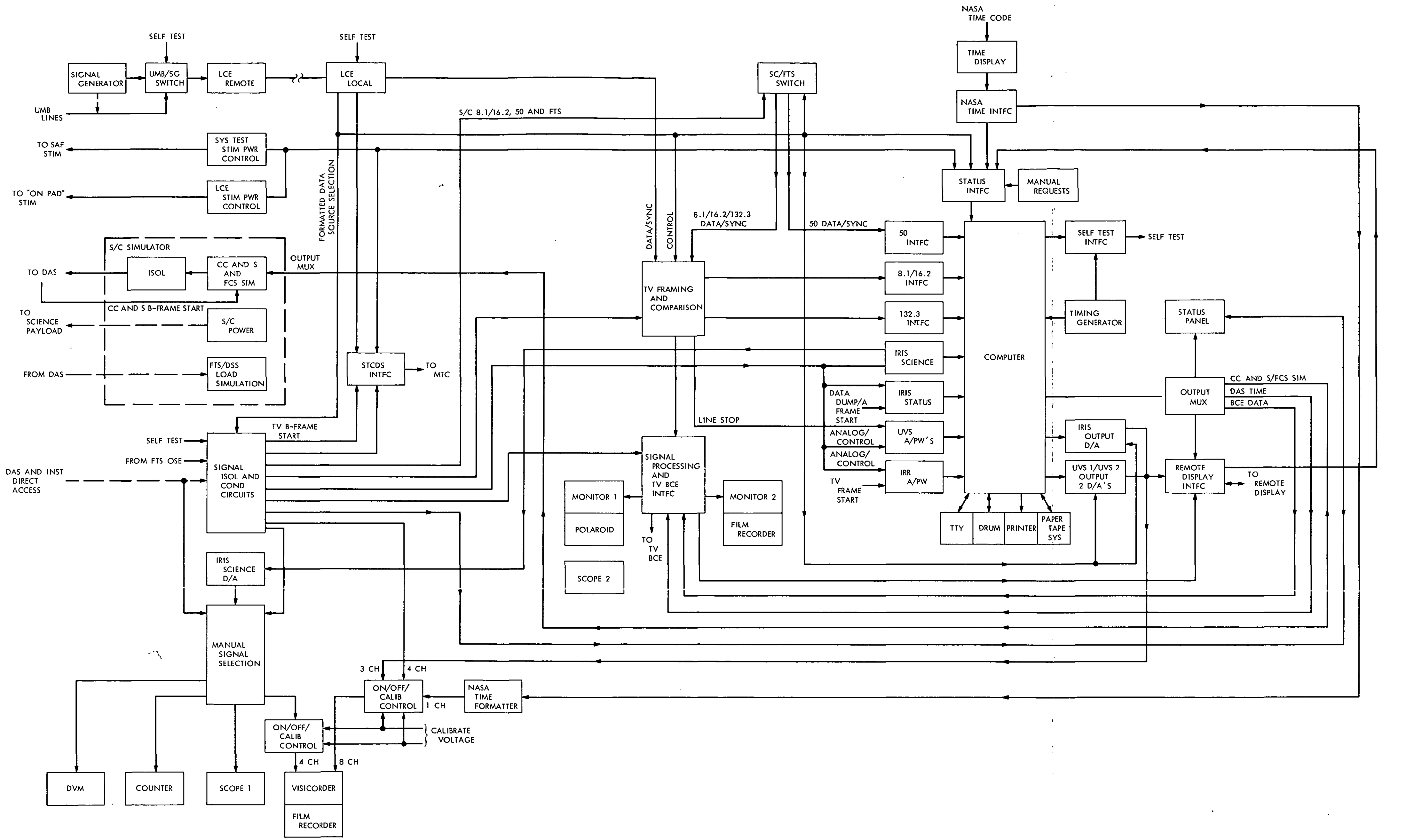

Fig. 4. SOSE block diagram

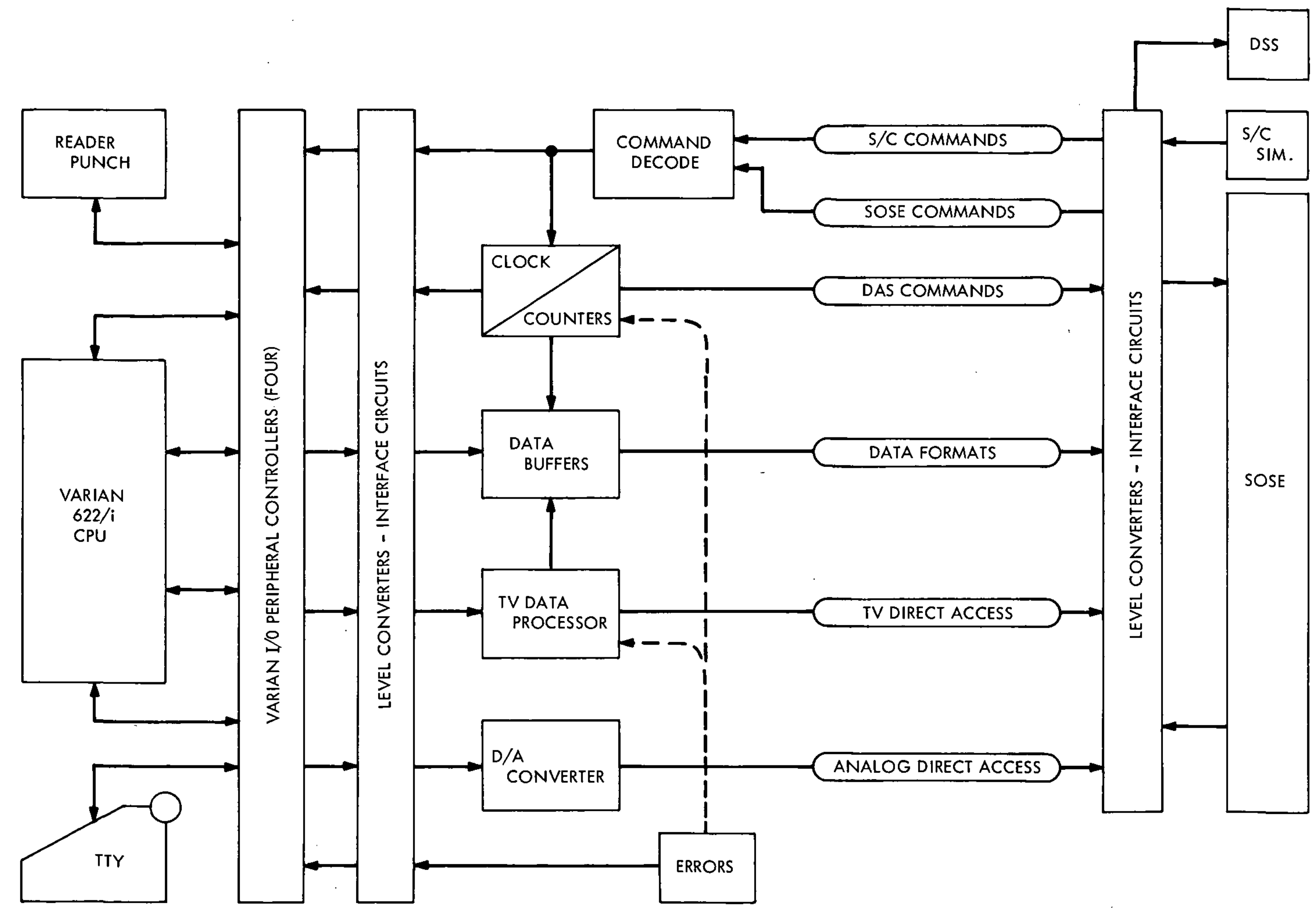

Fig. 5. Payload simulator block diagram

NASA — JPL — Coml., L.A., Calif.